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	Patents ADP number *(if you know it)*	~~1867002~~ 6300388001
	If the applicant is a corporate body, give the country/state of its incorporation	UNITED KINGDOM
4.	Title of the invention	MONITORING A COMMUNICATIONS LINK
5.	Name of your agent *(if you have one)*	
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	Patents ADP number *(if you know it)*	8772378001 ~~1867001~~
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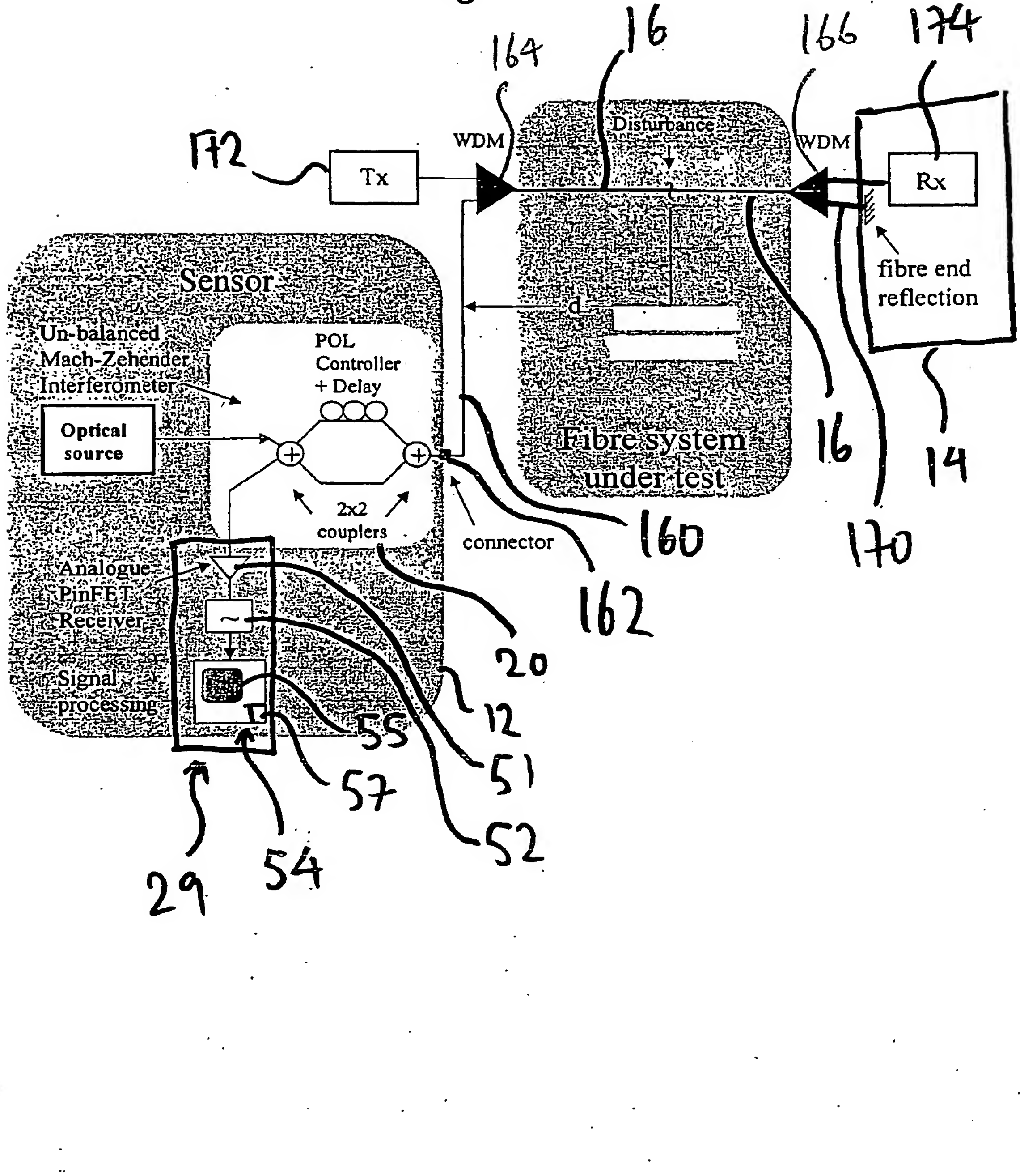
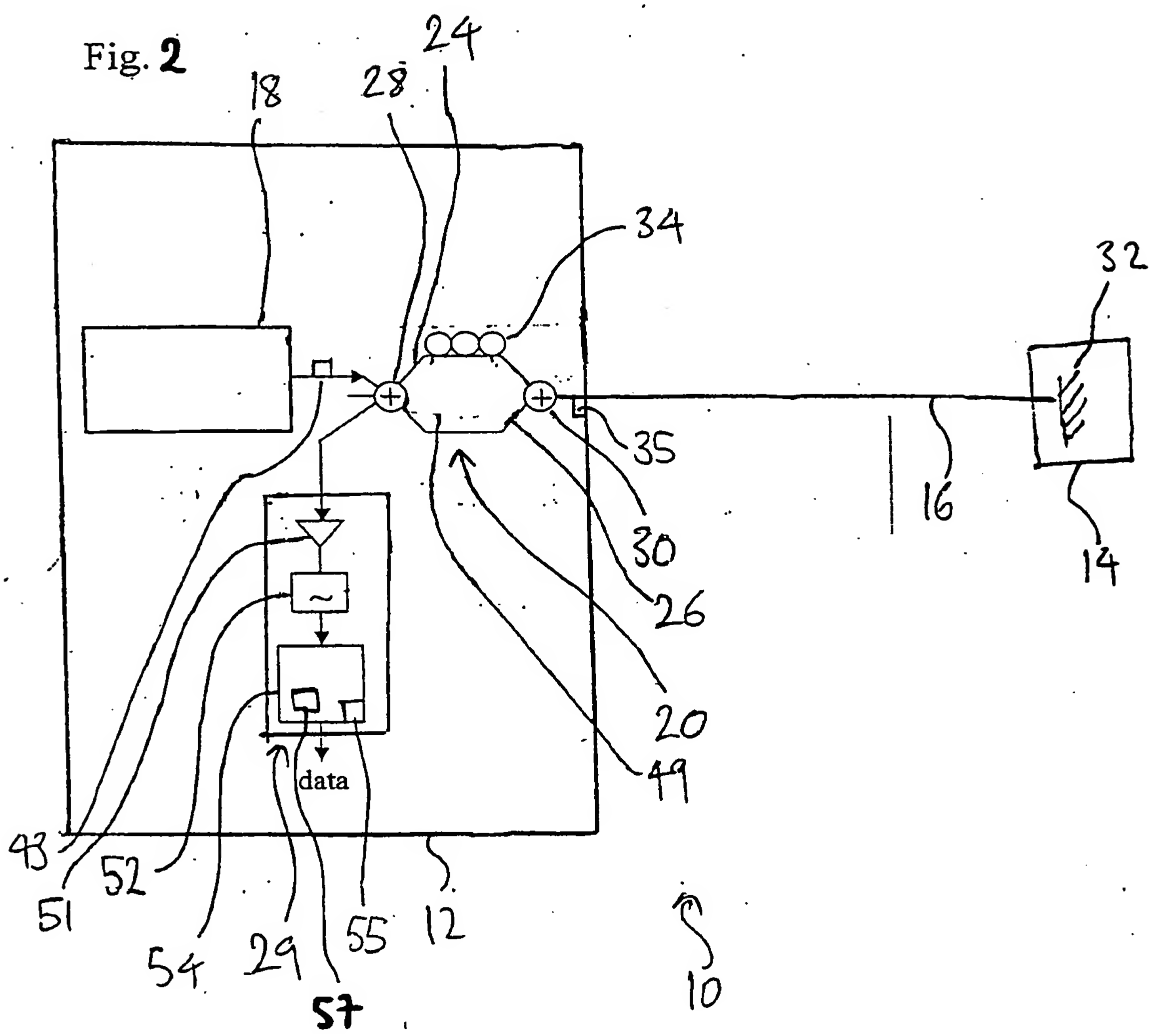
Fig. 1



Tx
172
164
16
166
174
WDM
Disturbance
WDM
Rx
fibre end
reflection
Sensor
Un-balanced
Mach-Zehender
Interferometer
POL
Controller
+ Delay
d
Optical
source
Fibre system
under test
16
14
2x2
couplers
connector
160
170
162
Analogue
PinFET
Receiver
Signal
processing
20
12
55
51
57
52
29
54

Fig. 2



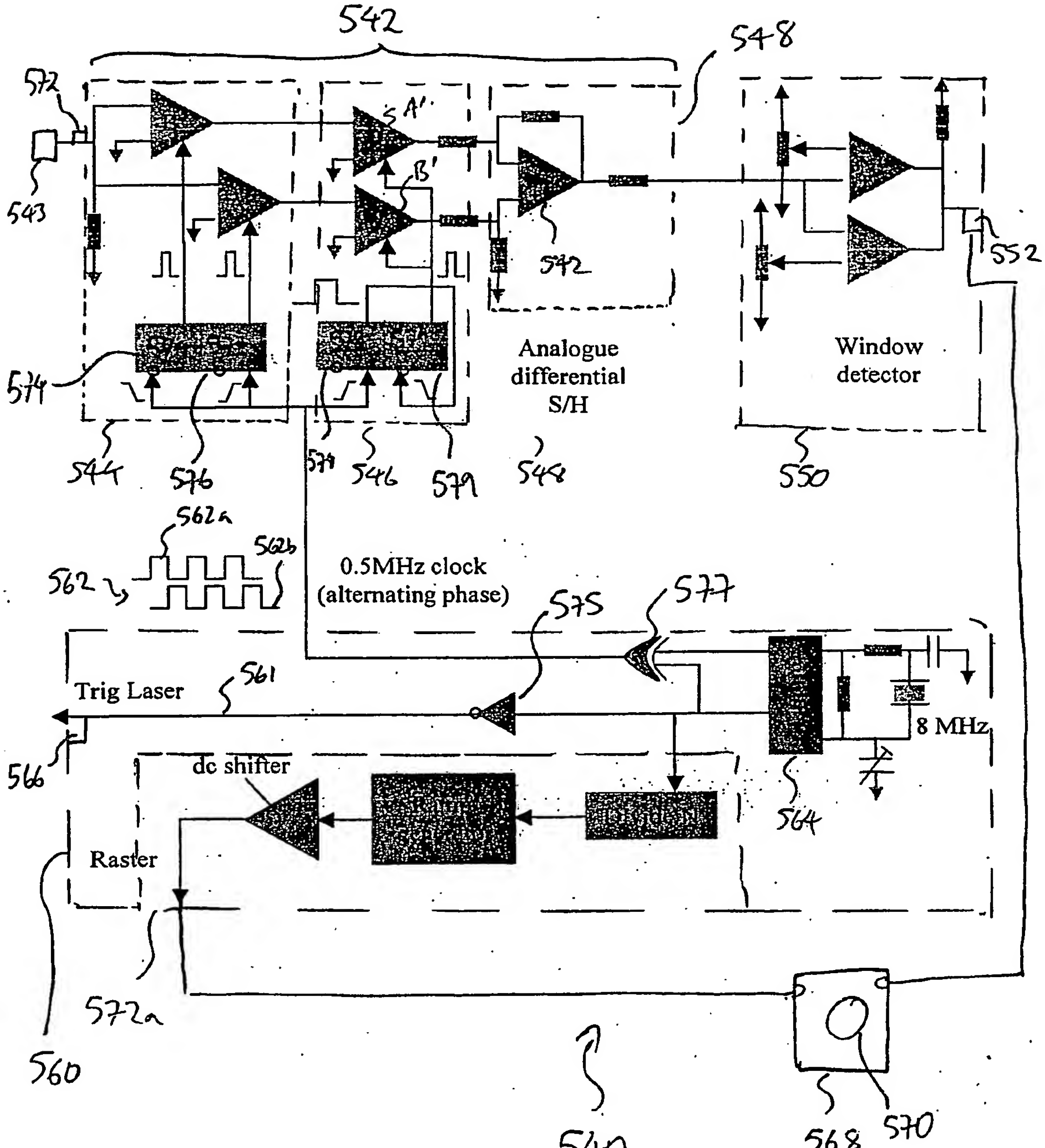

542
548
572
543
A'
B'
542
552
574
Analogue
differential
S/H
Window
detector
544
576
578
546
579
548
550
562a
562b
562
0.5MHz clock
(alternating phase)
575
577
Trig Laser
561
8 MHz
566
dc shifter
564
Raster
572a
560
540
568
570

Fig. 3

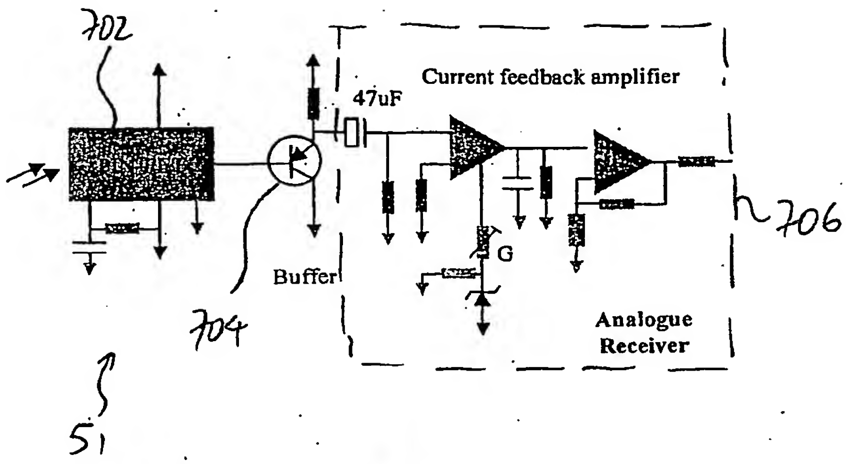


Fig. 4

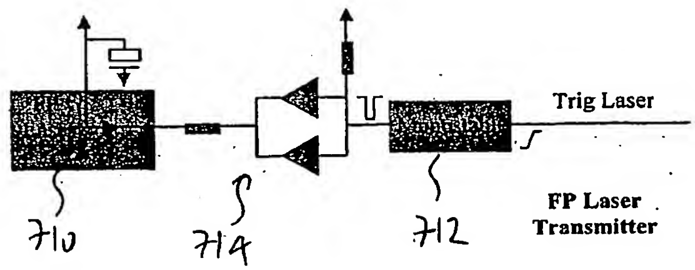


Fig. 5a

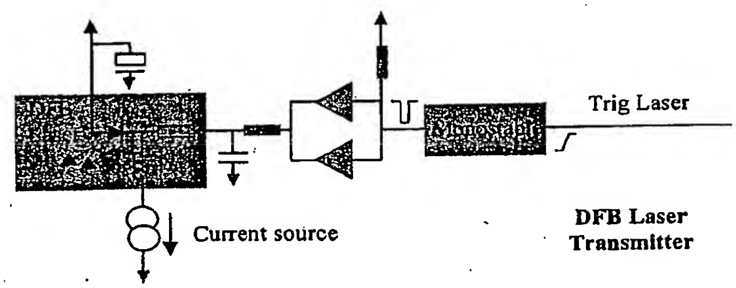
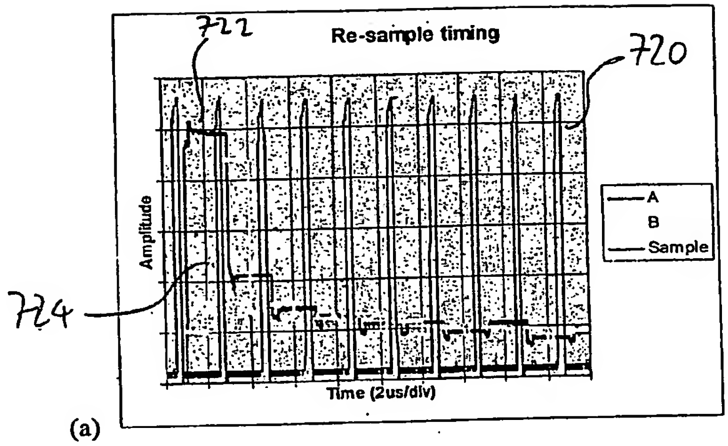
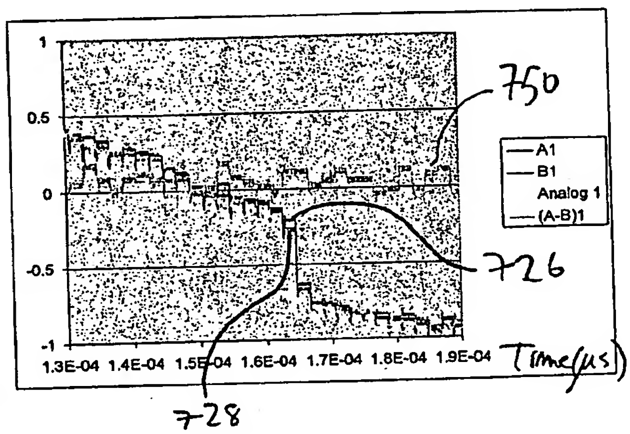


Fig. 5b.



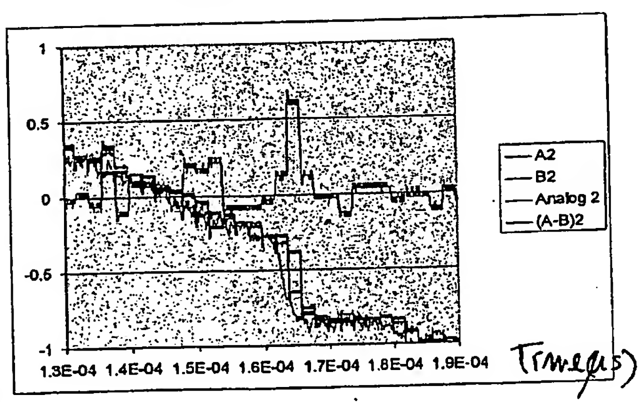
(a)

Fig.6a



(b)

Fig. 6b



(C)

Fig. 6c

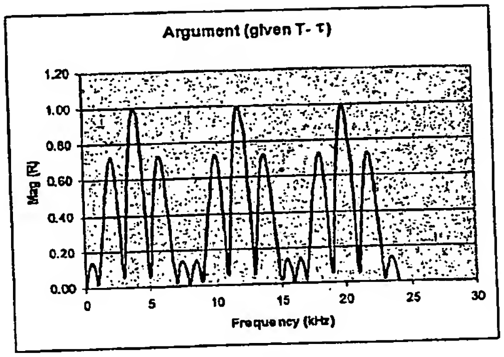


Fig 7a

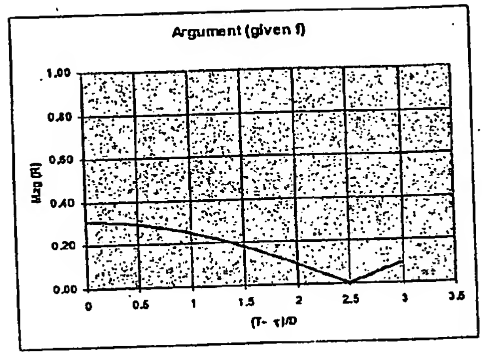


Fig 7.b

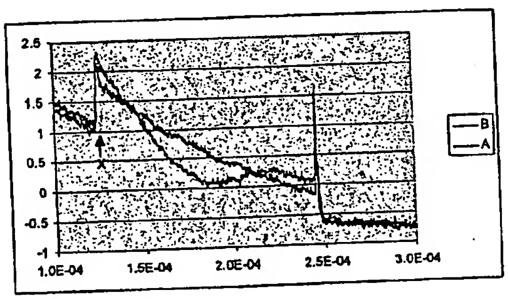


Fig. 8a

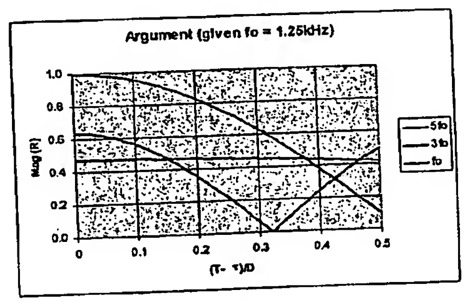


Fig. 8b.

Monitoring a communications link

The present invention relates to the monitoring of a communications link, in particular to the monitoring of physical disturbances of a communications link.

It is known to estimate the position of a disturbance in a medium by launching a test pulse in the medium, and monitoring the distributed backscattering of the test pulse, so as to detect any abnormalities in timed dependence of the returned signal.. An example of an abnormality could be a step change in the time-dependent amplitude of a return signal.

According to the present invention, there is provided a method of monitoring a transmission link to detect a physical disturbance of the link, the method including the steps of: copying, at least in part, an output signal from a source, such that there is a pair of signal copies; transmitting the signal copies onto a common communications link; receiving from the transmission link at least partially reflected copies previously transmitted thereon; combining the received signal copies of a pair so as to produce a combination signal; monitoring the combination signal to detect a disturbance feature in the combination signal, from which disturbance feature the presence of a disturbance can be inferred; and, from a temporal characteristic in the combination signal, estimating the position of the disturbance on the communications link.

Because for each signal generated by the source, that signal is copied before the (possibly modified) copies are combined, the need for a coherent signal to be transmitted on to the data link is reduced. One example of a disturbance feature could be a step change in the phase of the returning signals relative to one another (before the returning signals are combined, since in the combination signal the disturbance feature will normally manifest itself as an abrupt or step-wise amplitude change).

A characteristic of the combination signal indicative of a disturbance may be a change in the spectrum of the signal, or a change in amplitude in one or more frequency components of the signal. Alternatively, such a characteristic may be a change in the amplitude of the combination signal.

The output signals may be optical signals from an optical source, in which case the communications link will preferably be an optical fibre. A physical disturbance of the fibre is likely to lead to a strain in the fibre, which strain is likely to affect the optical properties of the transmission medium of the fibre. Such changes in the optical properties of the fibre can then conveniently be detected when the respective signals of a pair are combined. The steps of copying output signals and transmitting the signals will

preferably be carried out at a first location, the remote location being a second location, the first and second locations being preferably separated by at least 1 km, yet more preferably by at least 10 km.

If the signals are optical, the method can then advantageously be implemented in a Passive Optical Network (PON), the first and second locations being respectively sited at the respective head end and outstation of the PON. Furthermore, in such PON networks, each outstation can be connected to the head end by a respective fibre path, signals being carried along the path in both directions between the head end and the outstation. The communications link may be an optical cable having a plurality of optical fibres, or the link may be formed by a cable which carries data along a common fibre.

The output signals from a source will preferably have an irregular component, the step of copying the output signals resulting in that for each output signal, there is a pair of signal copies, the irregular component being common to each of the signal copies of a pair. The irregular component will preferably be random, or pseudo random (by pseudo random, it is meant that although in theory a component is possible to predict, the time or processing power required to do this will make it in practice impossible to predict). If the output signal has a waveform, the irregular component may be provided by the phase of the waveform, provided that the waveform has randomly occurring phase changes. In the case where the signals are optical, a source for such a waveform can conveniently be provided by an optical source having a short coherence time, preferably less than 10 pico seconds or even less than 1 pico second.

If the signals have a waveform, the combination will preferably be the interference or mixing of two waveforms.

Preferably, the copies of a pair of signals will be delayed relative to one another at the first location, such that a leading copy and a trailing copy are transmitted from the first location, the leading copy arriving at the second location before the trailing copy. This will make it easier for only one of the signal copies of a pair to have data modulated or otherwise mixed therewith at the second location. The signal copy can then be returned to the first location, where the leading copy will preferably be delayed relative to the previously trailing copy, such that both copies can be combined substantially in step with one another. In a preferred embodiment, the output from the optical source is fed to an interferometer stage, such as an un-balanced Mach Zehnder interferometer, where the signal is copied, one copy being channelled to one path of the interferometer, whilst the other copy is channelled to another path of the interferometer, the transit time associated with each path being different, such that a relative or differential delay results between the

time at which the signal copies are transmitted from the interferometer stage. The same interferometer stage can then be employed to re-align the returned signal copies of a pair in a particularly convenient manner, since the relative delay imposed in the outbound direction will be the same as the relative delay imposed in the return direction, this being in each case determined by the difference in the transit times of the two paths.

The differential delay will preferably be chosen in dependence on the average coherence time of the source. The differential delay will preferably be much longer than the coherence time, in order to make it difficult for an unauthorised person to extract data. Preferably, the ratio of the differential delay to the coherence time will be greater or equal to 10^3, yet more preferably 10^5 or even yet more preferably 10^7 or 10^9.

The signal will preferably be output from the source as a continuous stream in the manner of a carrier signal, the carrier signal being composed of a succession of wavetrains each having a respective coherence length or time. However, the output from the source may be pulsed or operate in burst mode.

Further aspects of the invention are provided in the appended claims. The present invention will now be described in further details below, by way of example, with reference to the following drawing in which:

Figure 1 shows a surveillance system according to the present invention;

Figure 2 shows a simpler system, but in more detail;

Figure 3 shows an signal processing system;

Figure 4 shows a photo receiver circuit;

Figure 5a shows an optical source circuit; Figure 5b shows another, less preferred optical source circuit;

Figures 6a-6c show measured traces of sampled return signals; Figures 7a and 7b show theoretical curves;

Figure 8a shows a measured return signal; Figure 8b shows a plurality of theoretical curves. .

Figure 1 shows the basic surveillance system architecture. In general terms, it comprises an optical source, an unbalanced Mach-Zehender interferometer (with a fibre delay and polarisation controller or de-polariser "POL" in one arm), an analogue optical receiver, filter and a signal processing system. The far end of the system under test provides a reflection (e.g., from an un-terminated fibre connector or a cleaved fibre end). A disturbance is shown at position *'d'* The diagram shows how the sensor might be wavelength multiplexed in order to protect a conventional optical data transmission system.

Light from the sensor source is split into two paths in the Mach-Zehender interferometer; one path is connected directly through and one goes via an optical delay line of several km of standard fibre and a polarisation controller or de-polariser. Thus the fibre under test conveys two copies of the source signal, one delayed by an amount *'D'* relative to the other. The phase, polarisation and amplitude of these signals are perturbed by the disturbance in both the forward and reverse directions of propagation. On returning to the interferometer the differential delay *'D'* is effectively un-done for one pair of propagating signals and thus ensures that they will be within the coherence length of the source –whatever it might be. Optical interference takes place at the 2x2 port coupler nearest the receiver creating an intensity modulated output signal that is sensitive to micro disturbances along the fibre under test.

Different types of disturbance will give rise to different characteristic signatures that can be identified by their temporal and spectral content. In practical experiments we have found that this system is so sensitive that it can detect the micro-strain changes induced by sound pressure waves picked up in the fibre under test (which therefore acts as a fibre microphone). By connecting the receiver output to a loudspeaker we could listen to the sounds (talking) and vibrations (movement) within the laboratory.

We have performed an initial theoretical analysis of the operation of this instrument that explains the nature of the experimental results observed. The analysis shows that the predominant cause of the observed signal is due to phase modulation of the test signal. We have also confirmed operation with different types of optical source, ranging from a highly un-coherent source of un-polarised amplified spontaneous emission (ASE) generated by a Erbium doped fibre amplifier (EDFA) (coherence length ~0.1mm) to a typical systems distributed feedback (DFB) laser (coherence length ~20m). We have also used a multi-longitudinal mode Fabry-Perot laser.

To explain in more detail the operational principles of the system of Figure 1, a simpler embodiment shown in Figure 2 will now be described in detail. Figure 2 shows a fibre monitoring system (also suitable for surveillance) in which a monitoring station 12 can monitor an optical communication link 16 extending between the monitoring station 12 and an outstation 14. The monitoring station 12 includes an optical source 18 with a short coherence time (random phase changes in the output providing an irregular component to the signal). A carrier signal having the form of wave train portions (hereinafter referred to as signals) from the optical source 18 are fed to an interferometer stage 20, here a Mach Zehnder interferometer having a first path 24 and a second path 26. The interferometer 20 includes first coupling stage 28 for coupling optical radiation between the optical

source 18, the first and second paths 24, 26, and signal processing system 29. For light travelling in a forward direction, that is, towards the outstation 14, the first coupling stage 28 acts as a directional power (intensity) splitter, channelling light from the optical source 18 to each of the paths 24, 26, the power to each path being shared in a predetermined manner.

In the present example, the first coupling stage acts as a 50:50 power splitter, the power input to each path being equal. Consequently, for each signal provided by the optical source 18 in a given time interval, that signal is copied such that there is a first copy and a second copy, the first and second copies being duplicates of one another. One copy travels along the first path 24 whilst the other copy travels along the second path 26. A second coupling stage 30 is provided for coupling light between the first and second paths 24, 26 and an output 35 of the interferometer, which output is connected to the communications link 16. For light travelling in the forward direction, the coupling stage 30 acts as a combiner, combining the light from the first and second paths and channelling this combined light to the interferometer output 35. The first path of the interferometer has a delay stage 34 for increasing the transit time of light travelling therealong between the first and second coupling stages 28, 30, such that the transit time for light travelling between the coupling stages 28, 30 is higher along the first path 24 than it is along the second path 26. For each signal produced by the optical source, the interferometer 20 serves to delay one of the signal copies relative to the other signal copy, the signal copies being transmitted onto the link 16 at different times to one another.

The additional (differential) delay imposed by the delay stage 34 is much greater than the coherence time of the optical source 18. Thus, when light travelling along the first and second paths is recombined by the second coupling stage 30, the interference between light travelling along the two paths averages out, such that on average (over a timescale much greater than the coherence time) the amplitude of light upon recombination at the second coupling stage 30 is equal to the amplitude of light from the optical source 18 (neglecting the losses in the interferometer 20 due to absorption or backscattering, for example).

The outstation 14 comprises reflector means, such as a reflecting surface 32 for returning signals to the base station 12. Alternatively, the reflector means may be formed by a cleaved fibre end, a mirror grown on the end of the fibre, or a loop formed with a fibre circulator.

For return signals travelling in the return direction, that is, for return signals arriving at the interferometer 20 from the outstation 14, the second coupling stage 30 act

as a power splitter, in a similar fashion to the action of the first coupling stage 28 on light in the forward direction from the optical source 18. The first coupling stage 28 then serves to combine light from the first and second paths in the return direction, channelling the combined light to the signal processing system 29. In this way, return signals are copied at the second coupling stage 30, one copy being channelled along the first path 24, whilst the other copy is channelled along the second path 26.

The light source may be a Light Emitting Diode, a Fabry-Perot Laser Diode, or a source of amplified spontaneous emission such as an Erbium-Doped Fibre Amplifier or a Semiconductor Optical Amplifier, but preferably the light source will be a Super Luminescent Diode, since this has a broad and smooth power spectrum, and a short coherence time of about 0.5 ps or less. The radiation produced by the optical source will preferably be unpolarised, or alternatively a de-polarising unit 43 may be provided between the light source and the interferometer, for depolarising the light before the light is injected into the interferometer (the de-polarising unit may be for example, a Fibre Lyot de-polariser). A polarisation controller or de-polariser 49 will preferably be provided in one of the paths of the interferometer, here, the first path, so that the polarisation of light from the first path combining in the return direction at the first coupler 28 is at least partially aligned with that of the light from the other path. Typically, the source will operate at a wavelength of between 1 micron and 2 microns, preferably around 1.3 or 1.55 microns, in order to efficiently make use of standard telecommunications optical fibre, such fibre being configured to support single mode transmission at this wavelength. (However, using wavelength multiplexing to combine it with the data transmission system, the sensor could be operated at any single-mode wavelength. This is because the sensor signals are very low bandwidth and will not be unduly effected by fibre dispersion). Typically, the fibre will have a single core of a diameter which is around 9 or 10 microns. The delay fibre might comprise opposite sign dispersion fibre to the fibre under test in order to act as dispersion compensation. Alternatively, a dispersion compensator could be used.

For each signal generated by the source 18, there are four duplicates of this signal: a non-retarded signal S0 which has travelled along the second path 26 of the interferometer 20 in both the forward and reverse directions; a first retarded signal S1 delayed by a delay D in the forward direction (but not the reverse direction); a second retarded signal S2 retarded by the delay D in the reverse direction (but not the forward direction); and, a twice-retarded signal S3 retarded by a delay 2D, signal S3 being retarded in each of the forward and reverse directions.

The first and second retarded signals S1, S2 which are retarded in one direction only will returned to the first coupler stage 28 at the same time. In the absence of any disturbance in the fibre 16, these signals are copies of one another and the signals will interfere or otherwise combine constructively at the first coupler stage 28. However, if one of the pair of signals S1, S2 is modulated or otherwise modified by a disturbance along the fibre, the interference between the two signals will result in an interference signal having different spectral characteristics to the interference signal which would otherwise be produced in the absence of any disturbance to the fibre 16.

The signal processing system 29, receives from the coupling stage 28 an optical interference (combination) signal produced at the first coupling stage as a result of interference between signals which were originally copies of one another (e.g. S1 and S2). The signal processing system 29 is configured to determine from the combination signal if the fibre 16 has been disturbed, preferably physically disturbed.

A physical disturbance (caused for example by a displacement, an acoustic or ultrasound wave or other vibration) is likely to result in a change in the transmission properties of the link. In particular, in the case of an optical fibre link, a physical disturbance is likely to result in strain which will change the optical path link of the strained portion of the fibre, either through a change in the refractive index, polarisation, or a change in the physical length, or a combination of these. .

A physical disturbance in the link, in particular an optical fibre link 16, is likely to result in an interference or combination signal from the first coupling stage 28, since when a disturbance occurs, the disturbance is likely to cause a phase and/or amplitude modulation in one of both of the (carrier) signals of a pair travelling along the link. However, the combination of signals will be the result of interference between on the one hand a carrier signal having been modulated by the disturbance at one time, and on the other hand, a signal modulated by the disturbance at another time, the two times being separated by the differential delay D. A disturbance is likely to increase the level of background noise. In general terms, the signal processing system 29 can then detect a disturbance by monitoring the background noise and detecting an increase in the background noise beyond a threshold value, noise levels beyond this threshold value being deemed indicative of a disturbance.

A disturbance is likely to change the spectrum of background "noise" as well as the level of noise, such that different disturbances will have different characteristic spectrum types. The distance between the base station and the point where a disturbance is occurring may also affect the spectrum. In general terms, the signal

the degree of correlation between a measured spectrum and a signature may then be generated, and an alarm may be triggered if the score value exceeds a threshold.

To determine the degree of correlation, the following steps may be performed; (a) for a frequency component of a measured spectrum, determine whether a signature spectrum has a frequency component within a tolerance level of the measured frequency component, incrementing a score value counter if a match is found; (b) for each frequency component in the measured spectrum above a threshold, repeat step (a) with respect to that signature spectrum, incrementing the score value counter each time a match is found; and, (c), associating a score value with the final value of the score value counter, for each measured spectrum in respect of at least one signature spectrum.

The memory location 55 may also store an amplitude value associated with each frequency component of a signature spectrum. The processor 57 may then perform a more sophisticated algorithm, in which when determining the degree of correlation between a frequency spectrum and a measured spectrum, the similarity of the frequency values as well as the amplitude of the corresponding components is taken into account when incrementing the score value counter. The memory location 55 will preferably be configured to store interference signals received within a time interval, the comparison between a measured spectrum and signature spectra being performed in respect of each captured or measured spectrum in each time interval.

Returning to Figure 1 in more detail, the transmission link 16 is coupled to the monitoring system by a coupling fibre 160, which coupling fibre is connected to the monitoring station 12 at a connector 162. Radiation from the coupling fibres 160 is introduced into the link 16 by a first wavelength coupler 164 at the input end of the link 16 (i.e., the monitoring side), whilst at the output end of the link 16 (away from the monitoring side), there is provided a second wavelength coupler 166, such that light from the link 16 can be coupled to an end reflector 168 located at the end of a termination fibre 170, the termination fibre 170 connecting the second wavelength coupler 166 to the reflector 168. A transmitter station 172 and a receiver station 174 are respectively connected to the first and second wavelength couplers 164, 166.

The wavelength couplers 164, 166 are each configured such that using a wavelength division multiplexing technique, data can be transmitted over the link 16 between the transmitter and receiver stations 172, 174 at one wavelength, whilst radiation from the monitoring station 12 is carried at another wavelength over the fibre link 16, radiation from the transmitter station 172 and the monitoring station 12 being transmitted over a common fibre or medium within the link 16.

At the second wavelength coupler 166, light at the wavelength of the source 18 is directed from the link 16 and to the termination fibre 170, where, upon reflection at the

generate a raster signal which can be fed to the oscilloscope for generating a two-

dimensional display. Further gates 575 and 577 are included in the timing control circuit as indicated in Figure 3.

The clock pulses in the present example are at a frequency of 0.5MHz and are of the alternating phase type, that is, a wave train is generated with one phase 562a, and another train is generated at a phase shift of 180 degrees. The timing control circuit is configured such that the clock phase alternates on every trigger pulse to the optical source 18, and also synchronises the restor generator for generating the two-dimensional display. The two-dimensional representation will allow the time-evolution of the backscatter signal from each position in the fibre to be observed on the display 570 of the storage oscilloscope 568. The digital and analogue electronics used separate, regulated and de-coupled power supplies (in Figure 3, upward pointing arrow indicates a connection to a positive supply rail, whilst downward pointing arrows show a connection to ground or the negative supply rail).

In more detail, the sampling unit 542 includes a copying stage 572, which could be a simple "T" connector, for generating copies of the input signal (that is, the OTDR signal or a signal equivalent to the combination signal in the electrical domain).

The sampling stage 544 has two sampling amplifiers A, B, each of which are triggered to sample by a respective pulse unit 574, 576, the pulse units being fed with clock pulses from the timing control circuit 560. The copies A and B each respectively enter amplifiers A, B, where respective discreet-time pulse amplitude copies are generated. The pulse units 574, 576 are arranged such that the sampling instance of the two copies (A and B) is offset by a range resolution interval, here one microsecond. The signals from sampling amplifiers A, B are then passed respectively to further sampling amplifiers A' and B' of the alignment stage 546, where these samples are then re-sampled.

The further sampling amplifiers A', B' or equivalently sampling gates are triggered by respective pulse units 578, 579 (the pulse units 578, 579 being driven by clock pulses from the timing control unit 560). The further amplifiers A', B' are operated in such a way (through the timing of the pulse units 578, 579) that the re-sampled signals of the A copy precede the sampled signals of the B copy: this means that the A samples originate from a range resolution cell which immediately precedes that of the B signal. The result of this re-sampling strategy is that sampling points "walk" along the fibre link 16 (separated by a distance corresponding to one microsecond), but with a step size of two microseconds (assuming the pulse initially transmitted by the optical source onto the fibre link 16 are one microsecond in duration).

The comparison stage 548 includes a difference amplifier 549 for evaluating the difference between the twice sampled signals A and B: that is, the output of the difference amplifier gives an output related to A - B. Because the A and B traces are re-aligned before being compared, it may be considered that the a values related to slope or gradient of the time-dependence of the signals is obtained. Effectively, the time-dependent sampled signals are differentiated: that is the difference between neighbouring samples is evaluated (although the samples need not necessarily be immediately neighbouring samples).

The photo receiver 51 is shown in more detail in Figure 4. Light from the coupler 28 is incident on a photo transistor 702, here a PIN-FET, which produces an electrical output that is fed to a bipolar transistor 704, acting as a buffer, before being fed to a variable gain current feedback amplifier 706. In Figure 5a, the optical source 18 is shown in more detail. Light for transmission onto the link 16 (through the interferometer stage) is generated by a Fabry Perot Laser 710. The trigger signal 561 from the timing control circuit 560 is received at a mono stable pulse generating unit 712, which generates a pulse for each trigger signal received, this pulse being amplified by a booster amplifier 714 so as to drive the laser 710. Figure 5b shows an alternative in which a DFB laser is used. However, it has been found that a DFB laser can give rise to coherence noise, and instability.

Figures 6a, 6b, and 6c show the sampling waveforms at various points in the signal processing unit 540. Figure 6a shows the position of the regular (re)sampling pulses relative to the pulse amplitude modulated sampled waveforms A and B. In Figure 6a, repeating sample pulses 720 are shown (darkest line). The A sampled signal (the output from amplifier A) is shown in the grey line 722, whilst the B sampled signals (that is, the output from the amplifier B) are shown by the lighter line 724. As can be seen from the "A" trace, the amplitude of the backscattered signal decreases as the elapsed time (since the launch of a test pulse from the optical source) increases, as is normally expected in OTDR. The amplitude of the "B" trace 724 likewise decreases with the elapsed time, but is shifted relative to the A trace.

In Figure 6b the re-sampled signals A and B (that is, outputs from sampling amplifiers A' and B') are shown, the A sample being the darker trace 726 whilst the B sample is the lighter trace 728. Because the two signals have been re-sampled, as explained above, these are now aligned. The difference in the A and B re-sampled signals (that is, the output (A – B) from the comparison stage 548) is shown by the lighter trace 730. Although there are no apparent features indicating a disturbance in this trace,

the (A – B) trace of Figure 6c clearly shows a feature at about 165 microseconds (the time corresponding to the step change in curves A and B). The difference between the traces of Figures 6b and 6c is that the clock signals driving the sampling amplifiers has zero phase shifts in Figure 6b, but a 180 degrees phase shift in Figure 6c. This illustrates how by generating a first (A – B) trace with a clock signal at one phase, and another (A - B) trace with the clock at a phase offset by 180 degrees, gaps between the sampling cells in one trace can be effectively removed by sampling in cells which are shifted by one cell length. In this way, the resolution of the present embodiment is one microsecond, corresponding to a length of the order of 100 metres. Thus, the resolution length is equivalent to the pulse length of the test signals from the optical source 18.

In summary, of one of the embodiments of the invention relates to the monitoring a communications link, particular to detect a physical disturbance in the link. The position of the disturbance is estimated using optical time domain reflectometry. A series of low coherence test pulses is launched into an optic fibre via an unbalanced Mach Zhender interferometer (forward direction). The time dependence of the relative phase of the backscattered return signals (that is the returned signal copies of a pair) is monitored by means of the interferometer for abnormalities due to external disturbances in order to allow their positions to be determined. From the elapsed time between transmission of a test pulse and the arrival time of a abnormal feature in the backscattered signal, the position of the disturbance causing the abnormality can be inferred.

As can be seen from the above description, the present embodiment provides a simple and sensitive way of monitoring a fibre to detect a disturbance, if any, in the fibre. The embodiment can be useful as a general surveillance technique, for example if the fibre being monitored is placed so as to be mechanically coupled to an object or surface being monitored. In addition or alternatively, a fibre that is being used for communication can be monitored whilst communication traffic is being carried by the fibre, and, if a disturbance on the fibre is detected, the position of the disturbance can be evaluated.

The following explains the theory behind at least some aspects of the above embodiments: scalar Interferometer OTDR Theory. The theoretical operation of the interferometer OTDR using a pulsed probe signal to excite a distributed Rayleigh backscatter signal in order to give disturbance position information is rather involved. The problem is best understood by first considering a discrete reflector and a continuous wave excitation signal.

Thus, equation (4) shows that the resulting signal with an OTDR can be interpreted using the simpler formulation of equations (1) and (2). However, the signal at each resolvable

CLAIMS

1. A method of monitoring a transmission link to detect a physical disturbance of the link, the method including the steps of: copying, at least in part, an output signal from a source, such that there is a pair of signal copies; transmitting the signal copies onto a common communications link; receiving from the transmission link at least partially reflected copies previously transmitted thereon; combining the received signal copies of a pair so as to produce a combination signal; monitoring the combination signal to detect a disturbance feature in the combination signal, from which disturbance feature the presence of a disturbance can be inferred; and, from a temporal characteristic in the combination signal, estimating the position of the disturbance on the communications link.

2. A method as claimed in claim 1, wherein the position of the disturbance is estimated by measuring the time of arrival of the disturbance feature.

3. A method as claimed in claim 1 or claim 2, wherein the combination signal is sampled at a first set of spaced apart temporal positions and at a second set of temporal position, and a wherein the first and second sampled sets are compared in a comparison step.

4. A method as claimed in claim 3, wherein the temporal positions of the first and second sets are interleaved.

5. A method as claimed in claim 3 or claim 4, wherein the comparison step involves generating a set of data which is at least in part dependent on the difference between the first and second sets.

6. A method as claimed in any preceding claim, including the step of, in dependence on at least one characteristic of the combination signal, generating a disturbance alert signal.

++++end

7. A method as claimed in any of the preceding claims, wherein the output signals are optical signals.

8. A method as claimed in any of the preceding claims, including the step of generating the output signals.

stage.

disturbance on the communications link.

24. Communications apparatus as claimed in claim 23, wherein a coupling stage is provided which acts on the one hand as the copying stage for signals travelling in an outbound direction towards the common communications line, and on the other hand, as the combination stage for signals travelling in a return direction from the common communications link.

25. Communications apparatus as claimed in claim 24, wherein the copying stage and the transmission stage are connected by a first path and a second path, each of the first and second paths extending between the copying stage and the transmission stage, the transit time associated with the first path being greater than the transit time associated with the second path, thereby forming an unbalanced interferometer.

26. Communications apparatus as claimed in claim 25, wherein the interferometer is an unbalanced Mach Zhender interferometer.

PATENT COOPERATION TREATY

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NOTIFICATION CONCERNING SUBMISSION OR TRANSMITTAL OF PRIORITY DOCUMENT

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Applicant BRITISH TELECOMMUNICATIONS PUBLIC LIMITED COMPANY et al	

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